Potential carrying capacity of grazed pastures in southern Australia

G.R. Saul and G.A. Kearney,

Department of Natural Resources and Environment
Pastoral and Veterinary Institute, PB 105 Hamilton, Victoria, 3300, Australia
Email geoff.saul@nre.vic.gov.au

Summary

Data from farm paddocks in south-eastern Australia, that were part of comparisons of productive pastures with typical farm pastures, were used to determine a relationship between climate and soil parameters and the carrying capacity of grazed pastures. Only the productive pastures grazed by sheep or beef cattle were included in the analysis. These paddocks were managed with assistance from experienced agronomists to ensure that soil fertility, pasture management and utilisation was improved compared to normal farm practice. Actual numbers of livestock grazed in the paddocks over a 12 month period were recorded and converted to dry sheep equivalents (dse) per hectare using standard values. Soil samples from all paddocks were analysed for common chemical values. Mean annual rainfall was obtained from the nearest meteorological station and the average length of the growing season (opening autumn rains until pasture growth ceased) was estimated for each paddock.

Regression analysis was used to relate carrying capacity to the climate and soil parameters. Carrying capacity was greatly influenced (P<0.001) by the average length of the growing season which accounted for 67% of the variance. There were also effects (P<0.01) of soil Olsen P and paddock size. For 20-40 ha paddocks with soil phosphorus (P) of Olsen 20 mg/kg, the model predicted that for growing seasons of 5, 7, 9 and 11 months, the carrying capacity was 10, 16, 23 and 30 dse/ha respectively. The percentage of variance accounted for was 70.9 and the standard error of observations was 3.96. Average annual rainfall was a less accurate predictor (percentage of variance 54%) of carrying capacity. The predicted carrying capacities can be used to benchmark current stocking rates against possible carrying capacity targets.

Introduction

Sheep and beef cattle are the dominant users of improved pastures in the 400-750 mm rainfall regions of southern Australia. There has been concern about the slow rate of productivity improvement in the grazing industries compared with intensive industries and broad-scale cropping enterprises (Anon 1996). A feature of these latter industries is the ability of farmers to accurately measure yields on particular paddocks or sections of the farm and compare these with industry standards.

Current benchmarks for assessing potential productivity of the grazing industries are based on rainfall. Using results from 17 stocking rate experiments conducted across Victoria during the 1960's, Hosking and Cameron (1985) suggested that improved pastures should carry 1dry sheep equivalent per hectare (dse/ha) for every 25 mm of rainfall above 250 mm. French (1987) used results from 9 experiments in South Australia and predicted that 1.3 dse/ha could be carried for every 25 mm of rainfall in excess of 250 mm. However, factors such as soil fertility, soil type and rainfall distribution also influence herbage production. Also, the data reported by Hosking and Cameron (1985) and French (1987) was collected from 0.5-2.0 ha plots and their relevance to farm paddocks is unclear.

During 1993-97, the Grassland's Productivity Project (GPP) was conducted on grazing properties across south-eastern Australia to encourage farmers to adopt productive pastures on their farms (Trompf *et al*. 1998). Data from this project was combined with information from other concurrent on-farm trials to determine benchmarks for the carrying capacity of paddocks across the region.

Methods

GPP was conducted on farms in Victoria, Tasmania, southern New South Wales, and the lower southeast, Adelaide Hills and Kangaroo Island regions of South Australia (Bennison and de Fegely 1998). Facilitators with a background in pasture agronomy and utilisation assisted farmers to compare Productive Pasture Technology (PPT) on one paddock with normal farm practice (Control) in an adjacent paddock (some farmers split an existing paddock in 2). PPT is a package of increased fertiliser application to correct nutrient deficiencies and higher stocking rates to use the additional pasture produced. It was developed at the Pastoral and Veterinary Institute, Hamilton, (Saul 1994) based on results from the Long-term Phosphate Experiment (Saul *et al*. 1999). While increasing fertiliser application and stock numbers are key components of PPT, application of lime, pasture manipulation, animal health, genetics and management were also considered and altered as necessary.

Facilitators assisted the farmers to determine the number of stock that could be carried on the PPT paddock, compared with the control paddock. Stock were regularly weighed and fat scored to determine the relative pressure on the animal in both paddocks. The aim was to maintain the stock in both paddocks at the same liveweight. If stock were heavier in the PPT paddock, stocking rates were increased. Paddocks records enabled the average stocking rate over a 12 month period to be calculated. Paddocks involved in GPP trials were set stocked during the comparisons although there were some periods in some paddocks when paddocks were not grazed to fit in with the overall farm management requirements, *i.e.* mating, shearing and autumn feeding. Any periods when paddocks were not stocked were recorded and average stocking rates adjusted accordingly. Stocking rates over the 12 month period were converted to dry sheep equivalents per hectare (dse/ha) using standard values (Beattie and Hamilton 2000). Most GPP comparisons ran for 3 years but the results reported in this paper were from the final year as it was expected that it would take at least 2 years for the impact of management changes to flow through the soil-pasture system. Only the results from the PPT paddocks were used to estimate carrying capacity.

Soil samples were taken from all paddocks in the final year of the comparisons to determine standard soil parameters including pH ($CaCl_2$), Olsen and Colwell phosphorus (P), available potassium (K), sulphur (S) and soil texture. Long-term mean annual rainfall was estimated from the nearest meteorological station. Facilitators also subjectively rated soil type, topography, and paddock size as shown below.
soil type: 1= sand, 2= sandy loam, 3= loam, 4= clay loam, 5= clay;
topography: 1= most of paddock < 5% slope, 2= most 5-10% slope, 3= most 10-20% slope, 4= most > 20% slope;
paddock size: 1= <10 ha, 2= 10-20 ha, 3= 20-40 ha, 4= >40 ha.

Facilitators estimated the long-term average length of the growing season (months) for each paddock, based on when the opening seasonal rains normally occurred in the area and when the pastures dried off in late spring. While the opening and closing rains occur at the same time in a particular locality, facilitators considered when the particular paddock stopped active growth taking into account soil type, aspect, topography, pasture type *etc*. The length of growing season was estimated in 2-week increments. In addition to the GPP data, results for 7 experimental comparisons of PPT conducted in Victoria in the same period were also included in the data reported in this paper.

Statistical analyses were undertaken using Genstat 5.42 (GenStat 2000). All factors, variates or qualitative, were regressed against carrying capacity (dse/ha). Significant factors (P<0.05) associated by univariate analysis were included in a multiple regression model. This model was modified in a stepwise manner for improvement due to possible quadratic and interaction effects. Simplifications of the qualitative factors were included as appropriate.

Results
A summary of the data is presented in Table 1. Despite an emphasis on improved soil fertility in the program, some paddocks were still below target levels of P, K and S, reflecting a history of sub-optimal fertiliser applications. Soils were mainly clay or clay-loams with most paddocks being flat or undulating in topography. There was a wide variation in average rainfall, length of the growing season and carrying capacity.

Table 1. Mean, maximum and minimum values for key data used in the regression analysis

	Carrying capacity (dse/ha)	Mean annual rainfall (mm)	Length of growing season (months)	Olsen P (mg/kg)	Colwell P (mg/kg)	K	S	Soil pH (0-10 cm, $CaCl_2$)	Soil type score (1= sand, 5=clay)	Topography Score (1= flat, 4=steep)	Paddock size score (1=<10 ha, 4=>40 ha)
Mean	20	670	7.7	14	39	192	11	4.7	3.1	1.6	2.0
Maximum	42	1000	12.0	37	115	550	47	6.4	5.0	3.0	4.0
Minimum	4	425	5.0	6	12	34	2	3.9	1.0	1.0	1.0

Equation 1 presents the relationship between carrying capacity, average length of the growing season, soil fertility and paddocks size. Estimated carrying capacities for different paddocks are shown in Table 2. Growing season accounted for 67% of the variance in carrying capacity with small improvements when Olsen P and paddock size were added. Colwell P gave similar precision as Olsen P. There were few large (score 4) paddocks and scores were therefore simplified to <20 ha and >20 ha. This resulted in paddock size becoming a significant factor with larger paddocks having a lower carrying capacity than <20 ha paddocks. No other soil or paddock parameters were significant and the inclusion of quadratic or interaction factors did not improve precision.

Equation 1. Relationship between average growing season, Olsen P, paddock size and carrying capacity.

Carrying capacity (dse/ha) = ***a*** *+* ***b****(Growing season months) +* ***c****(Olsen P mg/kg)*
Percentage of variance accounted for 70.9. Standard error of observations, 3.96.

Estimates of parameters for equation 1

	Estimate	Standard error	Significance
a Constant (<20 ha paddocks)	-8.30	1.89	P<0.001
a Constant (>20 ha paddocks)	-11.05	2.07	P<0.001
b Growing season (months)	3.41	0.252	P<0.001
c Olsen phosphorus (mg/kg)	0.178	0.0639	P=0.006

Table 2. Carrying capacity (dse/ha) based on length of the growing season (months), Olsen phosphorus (mg/kg) and paddock size predicted from equation 1.

Growing season (months)	5	6	7	8	9	10	11	12
Less than 20 ha paddocks								
Olsen phosphorus 10 mg/kg	11	14	17	20	24	28	31	34
Olsen phosphorus 20 mg/kg	12	16	19	23	26	29	33	36
More than 20 ha paddocks								
Olsen phosphorus 10 mg/kg	8	11	15	18	21	25	28	32
Olsen phosphorus 20 mg/kg	10	13	16	20	23	27	30	33

Equation 2 shows the relationship between carrying capacity, soil fertility, paddocks size and average annual rainfall. Rainfall alone only explained 48% of the variance in carrying capacity. Again, Olsen P and paddock size were significant factors with Colwell giving similar accuracy. Given the relatively poor precision of this rainfall model, it could have been expected that other factors such as soil type or topography might have explained some additional variance. However, numerous alternative models were tested and no other factors were significant.

Equation 2. Relationship between average annual rainfall, Olsen P, paddock size and carrying capacity.

Carrying capacity (dse/ha) = ***a*** *+* ***b****(Average annual rainfall mm) +* ***c****(Olsen P mg/kg)*
Percentage of variance accounted for 54.4. Standard error of observations, 4.96.

Estimates of parameters for equation 2.

	Estimate	Standard error	Significance
a Constant (<20 ha paddocks)	-6.96	2.59	P=0.008
a Constant (>20 ha paddocks)	-9.68	2.80	P<0.001
b Average annual rainfall (mm)	0.0358	0.00395	P<0.001
c Olsen phosphorus (mg/kg)	0.254	0.0791	P=0.002

Discussion

There was a stronger relationship between the average length of the growing season and carrying capacity than average annual rainfall and carrying capacity. Given the relatively subjective assessment of the length of the growing season and that five different people made these assessments, it indicates that growing season is very strongly related to pasture production and hence carrying capacity of grazed pastures. Equation 1 predicts that each additional month of growth will allow an additional 3.4 dse/ha to be carried. If 1 dse requires around 350kg DM for maintenance, this is equivalent to 1200 kg/ha DM. Assuming 70% utilisation, this equates to an additional 2000 kg/ha pasture required or 67 kg/ha/day over a month, which is consistent with expected pasture growth in late spring in southern Victoria.

Soil P was a significant variable even though all PPT paddocks received at least 18 kg/ha/yr P throughout the GPP program. Some paddocks had a low fertiliser history prior to implementation of PPT and Olsen P was still below the optimum levels of 11-19 mg/kg (Saul *et al.* 1999), 2-3 years after higher fertiliser regimes were implemented (see Table 1). This highlights the importance of improving soil fertility if potential carrying capacity is to be achieved. The lower carrying capacity of large paddocks is as expected, as it is difficult to achieve high pasture utilisation in large paddocks or where topography and pasture type vary within a paddock.

Simpson *et al*. (2001) highlighted the problems of using average rainfall to predict carrying capacity. Whereas the French model predicted the carrying capacity for a farm on the south-west slopes of NSW as 28 dse/ha, predictions from Grassgro (Moore *et al.* 1997) suggested that 16 dse/ha was a realistic target. The reduced carrying capacity was due to the limited value from rain during summer storms and poor soil water holding capacity at the site.

Table 4 shows results for two GPP paddocks within 15 km of each other, in the mid south-east of South Australia. "Staude" is sandy range country while "Gale" is a peat soil. Using mean annual rainfall predicts the same carrying capacity for each paddock. However, the growing season was much longer on the peat and predictions based on the length of the growing season more accurately reflected the differences in actual carrying capacity.

Table 4. Effects of growing season and soil type on predicted carrying capacity

Paddock	Soil type	Mean annual rainfall (mm)	Average growing season (months)	Carrying capacity from growing season Equation 1 (dse/ha)	Carrying capacity from average annual rainfall Equation 2 (dse/ha)	Carrying capacity using French (1987) model (dse/ha)	Actual stocking rate (dse/ha)
Staude	Sand	670	6	14	19.5	22	19
Gale	Peat	670	11	31	19.5	22	30

Average length of the growing season is a robust variable that takes into account soil, climate and topography that all impact on pasture production. Hence, while it is less precise than measured rainfall values, length of the growing season is likely to provide more reliable predictions of carrying capacity than average rainfall. The results provide an easily calculated benchmark for the graziers over a wide range of environments to compare their current stocking rates with the possible carrying capacity of their farms. A comparison with stocking rate data from western Victorian farms (Beattie and Hamilton 2000) shows that most are substantially below their potential. While stocking rates on farms in the region have increased by 25 percent (2.7 dse/ha) over the past 5 years, there is still considerable potential for most farms to safely increase stock numbers.

The French (1987) equation predicted the potential carrying capacity based on the highest values recorded for that particular environment. Our predictions are a line of best fit through the available farm data so are more conservative. Some farmers will thus be able to achieve more than the predicted carrying capacities. However, care must be taken to ensure that pastures are not over-grazed leading to soil degradation and environmental damage. High fertility paddocks that support pastures with a high legume content and digestibility are vulnerable to overgrazing in late autumn (Saul, unpublished). Implementation of rotational grazing will allow a 10% increase in carrying capacity and maintain higher herbage mass in late summer (Waller *et al.* 2001) and so reduce the potential for wind or water erosion.

Acknowledgments
The authors acknowledge the data provided by GPP facilitators Jim Shovelton, Reg Hill, Jane Court and Alan Barrett. Sincere thanks also to the many farmers across southern Australia who participated in the program and collected the productivity data used in this paper. The Woolmark Company, the Department of Natural Resources and Environment, Victoria, and Pivot provided funding for GPP.

References
Anon (1996) Wool growing in Victoria, Pathways to Profitability. Natural Resources & Environment, Melbourne.
Beattie, L. and Hamilton, J. (2000) South West Monitor Farm Project. Natural Resources & Environment, Hamilton.
Bennison, L. and de Fegely, C. (1998) Grassland's Productivity Program- Final Report to Members. Grassland Society of Victoria, Mornington.
French, R.J. (1987) *Proc. 4th Aust. Agron. Conf.,* Melbourne, Victoria, pp 140-49.
GenStat (2000) GenStat for Windows Release 4.2. Fifth Edition. VSN, International Ltd., Oxford.
Hosking, J. and Cameron, I.H. (1987) Pastures in the 80's. pp 4-9. Pub. Dept. of Agric. and Rural Affairs, Victoria.
Moore A.D., Donnelly J.R., and Freer M. (1997) *Agric. Syst.* **55,** 535-82.
Saul, G.R. (1994) *Proc. of 9th Annual Conference, Grassland Society of NSW*, pp 66-72.
Saul, G.R., Cayley, J.W.D. and McCaskill, M. (1999) Making sensible fertiliser decisions: The Hamilton Long Term Phosphate Experiment. Agriculture Victoria, Hamilton.
Simpson R., Salmon L., Burbidge G., Donnelly J. and Moore A. (2001) *Proc. Grassland Society of Vic.,* **42,** 3-14
Trompf, J.P., Sale, P.W.G., Saul, G.R, Shovelton, J. and Graetz, B. (1998) *Aust. J. Expt. Agric*. **38**, 843-53.
Waller, R.A., Sale, P.W.G., Saul, G.R. and Kearney G.A. (2001) *Aust. J. Expt. Agric.* **41**, 1099-08.